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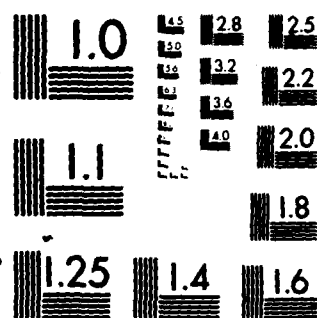
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ABILITY AND STRATEGY DIFFERENCES IN MAP  
LEARNING

Cathleen Stasz

August 1980

N-1569-ONR

The Office of Naval Research

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## **A RAND NOTE**

### **ABILITY AND STRATEGY DIFFERENCES IN MAP LEARNING**

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**August 1980**

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**Prepared For**

**The Office of Naval Research**

**Rand**  
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THIS REPORT

→ Describes the influence of individual differences in ability and subject-selected learning procedures and strategies for acquiring knowledge from maps. Verbal protocols were obtained from 25 subjects selected for their differences on psychometric tests measuring spatial restructuring and visual memory abilities. These protocols indicated a number of learning procedures and strategies that subjects used to focus attention, encode information, and evaluate their learning progress while studying a map. High-ability subjects differed from low-ability subjects in their recall of spatial attributes of the map, use of imagery for encoding spatial information and adoption of attention-focusing strategies to guide their approach to the map-learning problem.

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PREFACE

This Note was originally prepared as a paper for the proceedings of the NATO conference on Intelligence and Learning, held in York, England, in July 1979. It will appear as a chapter in M. P. Friedman, J. P. Das, and N. O'Conner (eds.), Intelligence and Learning (New York: Plenum Publishers, in press). The research summarized here was funded by the Office of Naval Research under Contract N00014-78-C-0042.

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SUMMARY

This Note describes the influence of individual differences in ability and subject-selected learning procedures and strategies for acquiring knowledge from maps. Verbal protocols were obtained from 25 subjects selected for their differences on psychometric tests measuring spatial restructuring and visual memory abilities. These protocols indicated a number of learning procedures and strategies that subjects used to focus attention, encode information, and evaluate their learning while studying a map. High-ability subjects differed from low-ability subjects in their recall of spatial attributes of the map, use of imagery for encoding spatial information, and adoption of attention-focusing strategies to guide their approach to the map-learning problem.

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## I. INTRODUCTION

The study of intelligent behavior in many task domains requires an understanding of the sources of individual differences which influence task performance. Two typical and important sources of individual differences are basic abilities (Cronbach & Snow, 1977) and the strategies that people use to perform a task (Johnson, 1978; Hunt, 1978). In this context, abilities are basic individual traits that are relatively enduring and resistant to change. Procedures and strategies, on the other hand, are assumed to be discretionary, trainable, and improvable with practice. This Note investigates how such differences influence the acquisition of knowledge from geographic maps. The research investigates expertise in map learning by analyzing differences between good and poor learners in terms of both their basic information-processing abilities and their self-selected learning procedures and strategies.

. . . . .

## II. BACKGROUND

Map learning is a constructive process which produces a mental representation of the space depicted on the map. This internal knowledge representation stores many types of information, including names, shapes, locations, and distances. Since map learning is an active, intentional process, it may be viewed as a problem-solving task (Newell & Simon, 1972) with a goal of achieving some memory representation of the map. The learner applies procedures and strategies as problem-solving operators to produce the memory representation. These subject-selected procedures are specific techniques for selecting information from the map to study and for encoding the information in memory. The procedures are of three types: attentional, encoding, and evaluation. Attentional procedures restrict the map information that the learner attends to at any point in time. Encoding procedures, such as rehearsal or imagery, elaborate the information in attentional focus and integrate it with information in memory. Finally, evaluation procedures monitor the learner's progress by considering what information has been learned and what remains to be studied.

In addition to these procedures, people often adopt global strategies for approaching the overall learning task. For example, an individual may decide to first learn the spatial information on the map, and then learn the verbal labels associated with the spatial locations. An individual's strategy may determine, in part, the procedures he or she chooses for accomplishing the learning task.

In previous studies of map learning (Thorndyke & Stasz, 1980), we collected verbal protocols from subjects attempting to learn fictitious, yet realistic, maps (see Figure 1). On each of six trials, subjects studied a map for two minutes and then attempted to reconstruct the map from memory. During study, subjects thought out loud, describing their attentional focus, their study procedures, and their evaluations of their learning progress.

Analysis of these protocols identified 13 procedures that subjects employed for focusing attention, encoding information, and evaluating the state of memory. Large individual differences were apparent both in subjects' use of these procedures and also in their rate of learning of map information. A comparison of good learners (subjects correctly recalling at least 90 percent of the map information by the final trial) and poorer learners showed that subjects differed primarily in the use of a few study procedures. Three of the procedures that differentiated good from poor learners involved the encoding of spatial configurations of map information. These were imagery, pattern encoding, and relation encoding.

Our results and informal observations suggested that specific abilities might also influence the learning process. In particular, we conjectured that subjects' spatial ability, rather than the use of particular procedures, might underlie the observed differences in performance. Since procedures comprise relatively low-level processes for manipulating information, subjects' choice of procedures might depend on their underlying abilities. For example, the best map learner reported that he had good visual memory and frequently used imagery to

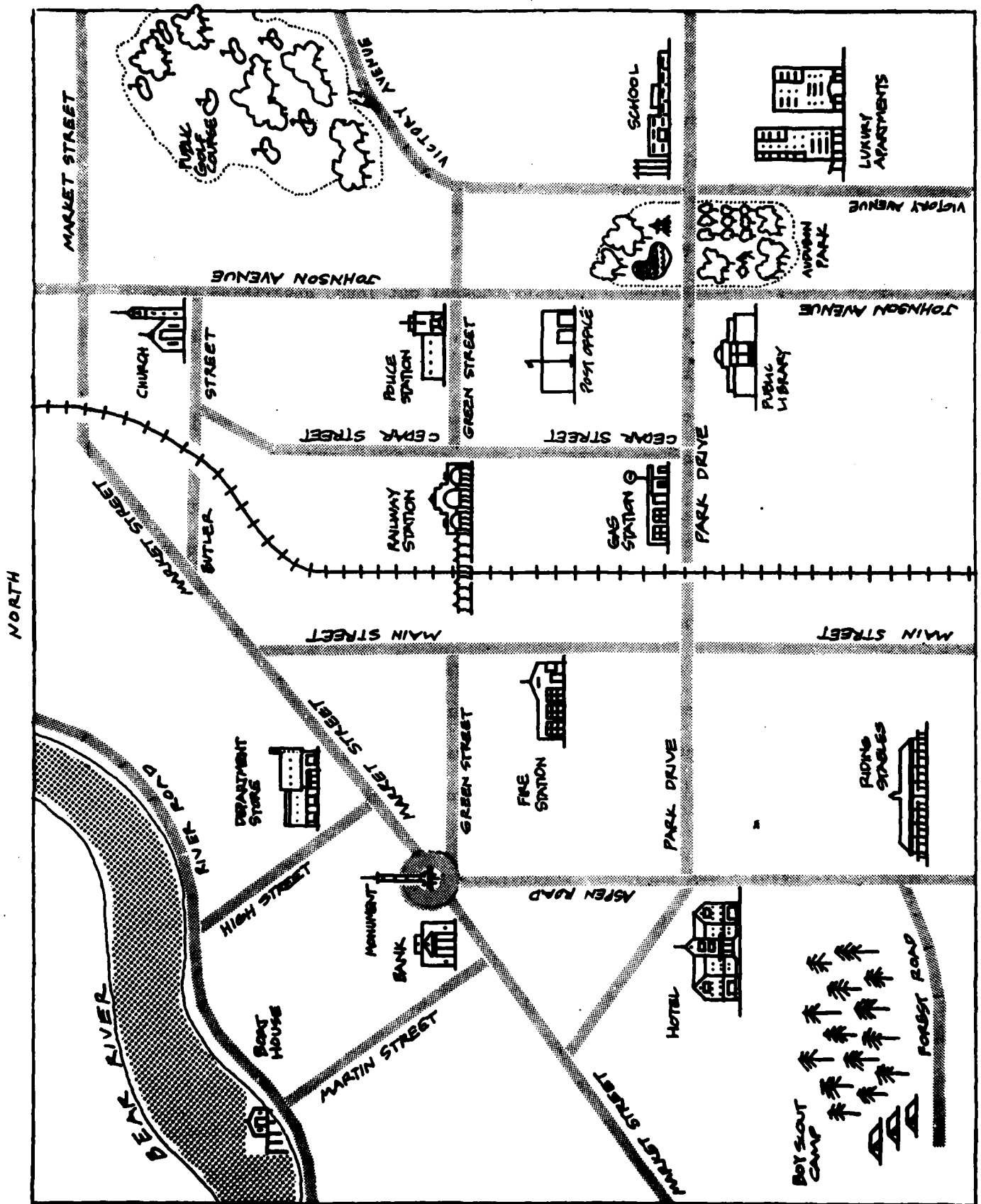


Fig. 1--The Town Map

learn and remember information. By contrast, the worst learner reported that he had never experienced having mental images. He used primarily verbal learning procedures, such as associating map information with previous knowledge. This subject did not attempt to learn the more complex spatial configurations on the map.

Ability differences might also influence subjects' skill at using a particular procedure. For example, we observed that poorer learners were frequently inaccurate in their evaluations, during study, of what they had already successfully learned. The evaluation procedure requires subjects to retrieve knowledge from memory and compare it to information on the map. In this process, subjects might evoke a mental image of stored knowledge for comparison with the map. This image may be clearer or more accurate for subjects with better visualization ability.

Finally, abilities may influence the selection of global learning strategies. In the map-learning task, all of the information to be learned is presented simultaneously rather than sequentially. Subjects must decide for themselves what information to learn first and how much time to spend studying each portion of the map. Individuals with spatial restructuring skill may employ strategies that subdivide the learning task. For example, subjects might adopt a divide-and-conquer strategy to help focus their attention on a subset of the information. They learn this information first, and then define and learn another subset. This strategy serves to structure the task into a sequence of smaller subproblems.



In sum, abilities appear to be a potentially important source of variation in map learning. The Thorndyke and Stasz (1980) results suggest how abilities and procedures might interact in the map-learning process: Procedure choice and successful procedure use might both depend on basic underlying ability differences. The present study was designed to investigate possible relationships between abilities, procedures, strategies, and map-learning performance.

### III. METHOD

#### SUBJECTS AND ABILITY MEASURES

Twenty-five subjects were selected from an initial group of 94, based on their performance on a battery of standard psychometric ability tests. The tests measured field-independence (Witkin & Goodenough, 1977), which represents spatial restructuring ability, visual memory, general intelligence, and verbal associative memory. We selected subjects who differed in visual memory and spatial restructuring skill but had equivalent scores on tests of general intelligence and verbal associative memory.

#### PROCEDURE

Subjects were individually tested on a map-learning task. For each of two maps, a town map and a countries map, subjects alternately studied and reproduced the map. The town map shown in Figure 1 depicted the streets and landmarks of a small town. The countries map shown in Figure 2 portrayed an imaginary continent with countries, cities, roads, railroads, and large geographical features, such as rivers and a mountain. On each of six trials, subjects studied a map for two minutes and then used as much drawing time as they wished. During study, subjects provided verbal protocols of their study behavior, including the strategies and procedures they were using. Following the final trial on each map, subjects answered eight location and route-finding questions from memory.

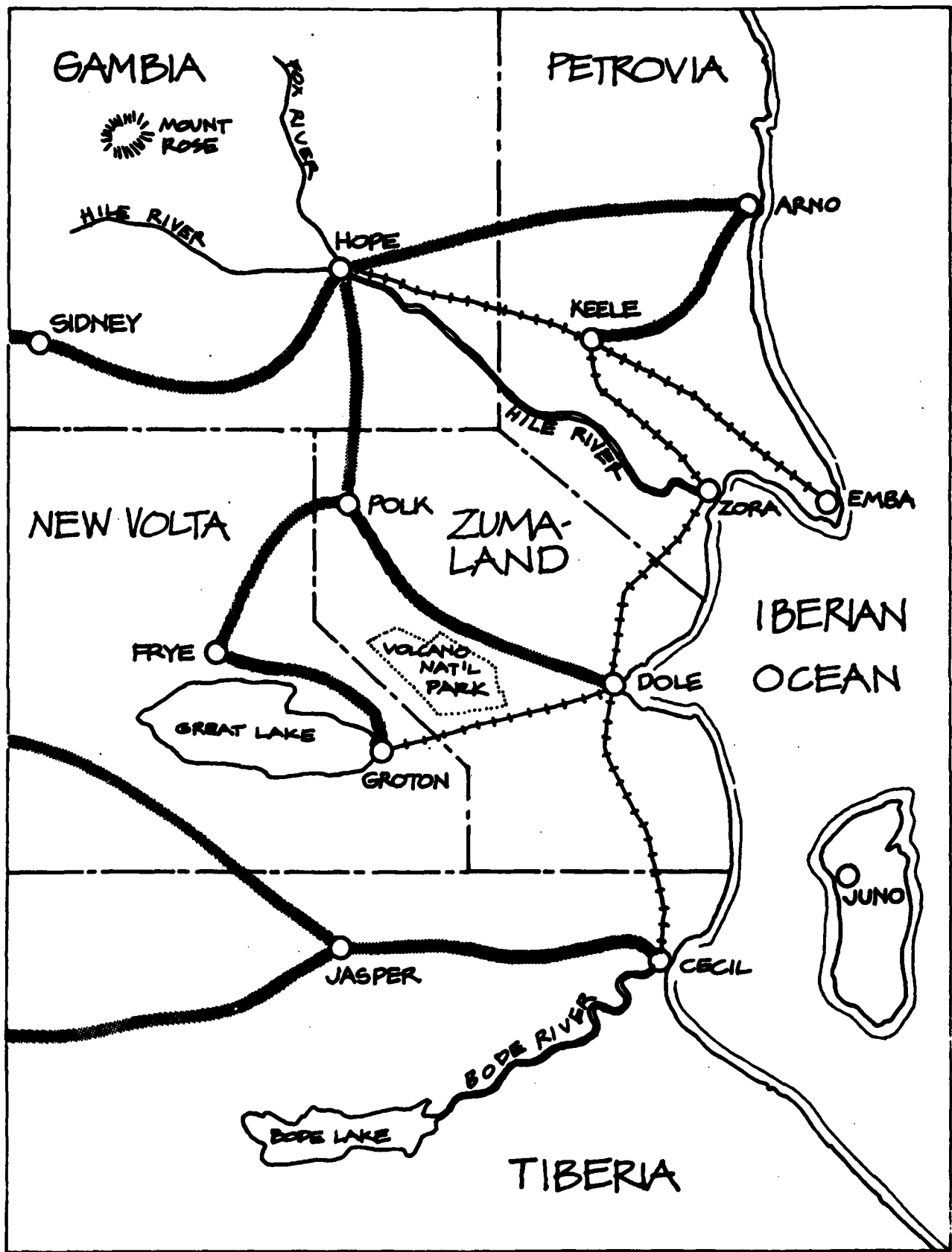


Fig. 2--The Countries Map

#### IV. RESULTS AND DISCUSSION

Although we performed a variety of analyses of the relationships between abilities, procedures, strategies, and map learning, this Note focuses on analyses contrasting performance of extreme ability groups. (Other analyses are reported in Stasz & Thorndyke, 1980.) Since tests of field-independence and visual memory were highly correlated ( $r = .66$ ,  $p < .01$ ), most subjects fell into two extreme groups: relatively field-independent, high visual memory (HIGHS;  $N = 10$ ), and field-dependent, low visual memory (LOWs;  $N = 10$ ). Data from these subjects were used for all subsequent analyses.

To determine the relationship between ability and performance, recall scores between HIGH- and LOW-ability groups were contrasted. For each subject, map reproductions provided three measures of recall performance: proportion of map objects correctly reproduced (both spatial location and verbal label correctly specified), proportion of spatial information correctly reproduced, and proportion of verbal information correctly reproduced. Reproductions were scored at each trial. For each subject, mean recall was calculated across trials and maps.

Table 1 presents mean recall scores for the two groups. Mann-Whitney U tests, with sample sizes of 10 and an alpha level of .05, indicated that HIGHS recalled significantly more complete elements and spatial attributes than did LOWs. The groups did not differ significantly in recall of verbal attributes. These findings replicate those presented in Thorndyke and Stasz (1980), who found that good and

Table 1  
ABILITIES AND PERFORMANCE

Item	HIGHS	LOWS
	Subjects	Subjects
	10	10
<hr/>		
<u>Recall (%)</u>		
Complete Elements	62.2*	50.2
Spatial Attributes	66.5*	54.0
Verbal Attributes	76.5	70.7
<u>Procedures (mean occurrences)</u>		
Imagery	5.4*	3.0
<u>Strategies (number of protocols)</u>		
Divide-and-Conquer	2	3
Global Network	10	1
Progressive Expansion	4	4
Narrative Elaboration	0	2
No Strategy	4	10

\*p < .05

poor learners differed in recall of complete elements and spatial attributes, but not of verbal attributes. In general, subjects had little difficulty learning verbal information on a map. The present result extends those findings by demonstrating that subjects' visual-spatial ability may underlie differences in recall.

To compare procedure use between HIGHS and LOWs, the average number of occurrences of each study procedure was calculated across trials and maps for each subject. HIGH subjects used all of the procedures that correlated with learning in this and previous studies (Thorndyke & Stasz, 1980) more frequently than did LOWs. However, only for the imagery procedure was this difference statistically significant. Thus,

the remainder of this Note will focus on differences in learning strategies.

Analysis of protocols and post-experiment interviews identified four strategies used by subjects. Each strategy entailed the use of particular procedures. In the divide-and-conquer (DC) strategy, subjects employed spatial partitioning to divide the map into distinct sections. Subjects would then study each section as a separate sub-problem. Subjects focused their attention on a single area, such as the northwest corner of the map in Figure 1, ignoring information outside the area of focus. They adopted a variety of procedures to learn the information in the identified area. Having satisfied themselves that they had learned this information, they then moved on to study a new section. This process continued until all sections of the map had been studied. On final trials, sections were appropriately integrated to maintain feature continuity.

The global network strategy (GN) subjects used the conceptual partitioning procedure to create a basic spatial framework which covered the entire area of the map. Rather than focusing on geographical areas, as in the DC strategy, subjects identified a certain conceptual category of information, such as streets, cities, or geographical features, to establish their initial framework. In Figure 1, for example, a subject might first study vertical streets and large features, including the river, railroad track, and golf course. This initial framework acted as a point of reference for learning new information. Subjects learned new elements by associating them to the previously learned anchor points.

Progressive expansion (PE), the third major strategy, was characterized by subjects' systematic movement of attention across the map. Typically, subjects chose a starting point, such as the right side of the map, and studied as many adjacent elements as possible in the allotted time. On successive trials they systematically focused on and learned new elements, moving across the map in a slow progression and in a consistent direction.

A few subjects employed the narrative elaboration strategy (NE). While the DC, GN, and PE strategies relied on specific attention-focusing procedures, the NE strategy did not. NE strategists created verbal associations, such as a story or narrative to remember map elements and their relationships. For the map in Figure 1, for example, one subject invented and rehearsed the following narrative: The butler went to church and saw cedar trees in the park. Thus, he created an association among Butler Street, Church, Cedar Street, and Park Drive.

To determine whether strategy use was related to subjects' ability, the study protocols were sorted into one of the four strategy groups, or into the "no strategy" group. Table 1 shows that 80 percent of the HIGH subjects' protocols exhibited one of the three attention-focusing strategies. None of the HIGH subjects used the NE strategy, and only four protocols were classified into the "no strategy" group. By contrast, 50 percent of the LOW subjects' protocols showed no consistent strategy. Eight protocols contained attention-focusing strategies, and two protocols used the NE strategy. To test whether the use of attention-focusing strategies versus no strategy was significantly different for HIGHS and LOWs, Fisher's exact test was computed

separately for each map. The tests indicated that the probability of chance differences at least this large in the tendency of the two groups to use a strategy is .08.



## V. CONCLUSIONS

These analyses suggest that both abilities and subject-selected learning techniques are important sources of individual differences in map learning. Visual-spatial ability may underlie the use of effective procedures for learning spatial information and the adoption of attention-focusing strategies. Both of these learning processes contribute to successful map learning. Thus, three key characteristics identify good map learners: (1) They adopt an attention-focusing strategy; (2) they use imagery to encode spatial information; and (3) they have high visual-spatial ability.

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